WORKING PAPER 129

A Framework for Efficient Wastewater Treatment and Recycling Systems

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International Water Management Institute

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Summary

This paper deals with the question of "how wastewater recycling can be made efficient in a developing country setting and a developed country setting?" Literature has shown that the use of un-treated/partially treated wastewater for irrigation is the main problem of wastewater use practices in developing countries. In the current paper, it is proposed that an institutional analysis can be conducted to determine the constraints for the current cost recovery of sewerage charges followed by a contingent valuation survey to determine the willingness of people to pay for increased sewerage charges. The key outcome of the two methods would be an appropriate cost (of wastewater treatment) sharing mechanism among various stakeholders, so that it is possible to treat wastewater to appropriate levels for recycling and hence make the practice socially and environmentally viable in the long run.

On the other hand, in developed countries, there is a need to increase the efficiency of wastewater recycling so that it competes efficiently with alternate sources of water. There are a number of different methods through which efficiency can be improved. However, for the current study, it is proposed to be improved through allocative efficiency. Wastewater recycling can fulfill different objectives and can be allocated to different sectors, namely, agriculture, industry, residential areas and urban recreational irrigation. A ranking exercise can be conducted for the different objectives among the stakeholders and each objective could be weighted accordingly. Once the objectives are weighted, the cost-effectiveness analysis can be used to evaluate the best sectors to which treated wastewater should be allocated to achieve the most desired objective. The approach outlined may be used further as the basis of a tool kit/decision support tool that can be employed in other circumstances and regions to allocate wastewater among different sectors.

Hyderabad (representing the developing country setting) and Melbourne (representing the developed country setting) are the two case study sites where the above two approaches will be tested as part of the doctoral research.

1. INTRODUCTION

Wastewater use[1] in agriculture has been a common phenomenon since the early ages. The nutritive value of the un-treated wastewater was recognized and accordingly used for the benefit of crop production. However, with increasing urban population, changing lifestyles and industrialization the quality of wastewater has deteriorated over the years and hence requires treatment before it can be recycled for any purpose. Since wastewater treatment is an expensive process, many of the underdeveloped and developing nations of Africa and Asia have not been able to treat their wastewater to appropriate levels and continue to use it in agriculture with deleterious long-term effects on soil, groundwater and human health. However, many of the water scarce cities in Europe, North America and Australia are able to treat their wastewater to appropriate levels and recycle it in industries, residential areas, urban gardens and sports lawns. While the lack of wastewater treatment to appropriate levels before use is a major problem in developing countries, the high cost of wastewater recycling is the major problem in developed countries.

The current paper is part of a doctoral research funded by the International Water Management Institute (IWMI) and Cooperative Research Centre for Irrigation Futures (CRC IF). It presents the gaps in wastewater research, the conceptual framework for the research and the methodology that can be used to tackle the problems associated with wastewater use in a developing country setting and wastewater recycling[2] in a developed country setting.

2. RESEARCH GAPS

The focus of most wastewater related research has been on the technical aspects and related issues of improvements in water quality and in minimizing environmental and health impacts. Little information has been produced on wastewater recycling from an economic and a social perspective. In particular, the costs and beneficial outcomes have been imprecisely quantified (DSE 2005). An exhaustive literature review shows that the key issues that are yet to be looked at from an economic perspective in wastewater recycling relate to pricing and allocative efficiency.

2.1 Pricing Recycled Water

According to Kularatne et al. (2005: 15), a number of issues need to be considered for appropriate pricing and when distribution mechanisms for wastewater are being developed. A very low price for wastewater may encourage inefficient use and may lead to the perception that it is a cheap and unlimited resource. This has been seen at Rouse Hill Recycled Water Project in northwestern Sydney. In another survey of residents living in a dual reticulation development, Marks et al. (2002) found that the majority of people expected to pay less for using recycled water because of the

[1] Use of un-treated or only partially treated wastewater for irrigation. It is a common practice in developing countries of Asia and Africa.

[2] Use of appropriately treated wastewater, which complies with the quality guidelines set by the Environment Protection Agency (EPA), in various sectors like agriculture, industry, recreation or households. Recycling is now being popularized in some water scarce cities of developed countries of Australia, North America and Europe.

water quality and restrictions on the people's use of this resource. However, focus group interviews of some of the residents by Kaercher et al. (2003) further indicated that lower price was necessary to encourage acceptance and investments in the up-front costs. On the other hand, if the price is set too close to the price of potable water, uncertain users will tend to use potable water for all purposes 'to be on the safe side'. Also, it needs to be noted that, agriculture alone is unlikely to support the level of funding required to make large-scale recycled water schemes viable. The cost of water has been shown to be 5-10% of the gross margin for horticultural crops. In a grower's decision making, the security of water is considered to be more of an issue than the cost. Gagliardo (2003) further asserted the need to show potential economic advantages in recycled water to encourage industrial use.

Recycled water is often more expensive than existing water supplies. For example, the 2004 prices for potable, surface and sub-surface water in Werribee Plains region ranged from AUD 134 to AUD 1,300 per milliliter (ml). Commercial prices for recycled water from the Western Treatment Plant for the proposed Moorabool Valley-Sutherlands Creek Scheme are estimated to range from AUD 870 per ml (peak) to 1,150 per ml (breakeven) if desalination is required.

Radcliffe (2003) argues that the costs and pricing mechanisms for wastewater are not transparent, as the true cost of irrigation, potable and recycled water is not reflected in the current prices. Radcliffe (2003) demonstrated considerable disparity in the pricing of water in a number of recycling schemes, ranging from AUD 700 to 830 per ml. This is compared to estimates of the true cost of reclaimed water that ranged from AUD 1,450 to AUD 3,000 per ml. Radcliffe (2003) attributed these significant differences to the following key issues:

- The cost and source of capital is generally not accounted for;
- Environmental externalities are frequently not costed; and
- The desire for higher profitability.

According to Muir (2006) price signals from the use of recycled water should be set at the long-run marginal costs of supply. If this is done then appropriate decisions on existing stand-alone schemes or the comparison of different proposals can be made.

Pricing wastewater is challenging and may vary from region to region depending on the regional variability. For a fair pricing policy, some further questions that need to be researched as per Kularatne et al. (2005: 16) are:

- How can the cost of treatment and distribution infrastructure of recycled water schemes be structured to promote uptake?
- Would private sector involvement in recycle schemes improve the commercial viability of recycle schemes?
- What incentives can improve commercial viability of large-scale recycle projects?
- What incentives should the government and water authorities adopt to improve the demand signals for recycled water schemes?

2.2 Allocative Efficiency

There are no clear guidelines on what factors need to be considered when allocating the recycled water to different sectors, so that overall economic efficiency is maximized. According to Freebairn (2003: 1) economic efficiency is maximized by allocating limited water among alternative uses so that marginal social benefits are equated across the different uses. Formally:

$$MSB_a = MSB_b \text{ for all a and b} \quad (1)$$

Where: MSB is the marginal social benefit and a and b are the different uses of water (i.e., irrigated crops, industry, household non-potable use and public recreational areas like parks) (see Figure 1).

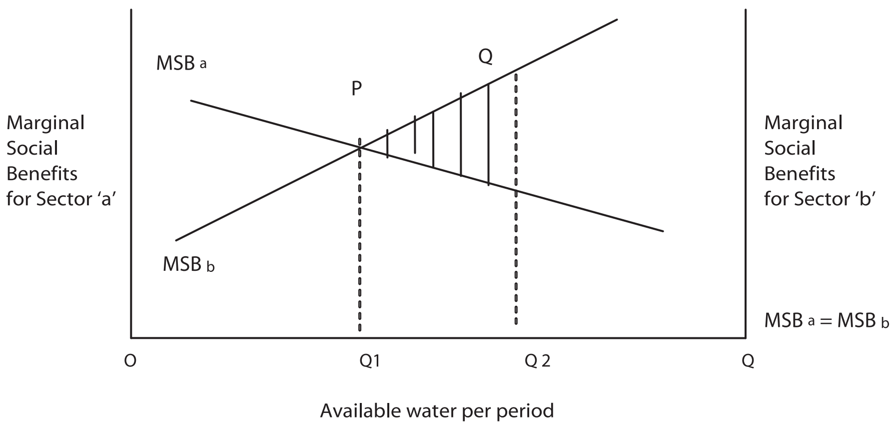

FIGURE 1. Application of marginal social benefits to allocate water.

2.3 Social Areas

Po et al. (2004) point out the obvious lack of social research in understanding the basis of public perceptions of water use and the psychological factors governing their decision making processes. They identified the following areas for further research:

- Understanding of judgement strategies used by people to make their decisions to accept or reject using recycled water.
- Identification of factors influencing people's risk perceptions in using recycled water.
- Investigation of the role of trust in the authorities and the limits in scientific knowledge in people's decision making processes to either accept or reject recycled water.
- Examination of the different ways and situations where factors such as health, environment, treatment, distribution and conservation issues can impact on the people's willingness to use recycled water.

- Examination of people's sensitivity with regard to the disgust emotion or "yuck" factor and the probability of avoiding recycled water.

- Understanding of why different sources and uses of recycled water can influence the decisions of people to use recycled water.

- Understanding of how perceived economic advantages in using recycled water can facilitate the decisions of people to use recycled water.

- Examination of the effectiveness of using Ajzen's Model of Planned Behavior in understanding factors that influence the people's willingness to use recycled water.

- No studies have been conducted to examine consumer attitude towards the environment and acceptability of produce grown with reclaimed water.

2.4 Other Areas of Concern

1. Need for improved understanding of the practice of wastewater use in agriculture in developing countries and to identify opportunities and constraints for the adoption of appropriate water quality guidelines (Faruqui et al. 2004: 173).

2. Conditions required for wastewater markets to function efficiently, specifically commercial feasibility for irrigation use of treated versus un-treated wastewater, pricing and supply mechanisms (Silva-Ochoa et al. 2004: 152).

3. Need for a uniform international approach to assess hazards and risks of wastewater use, while providing flexibility for individual countries to vary requirements to suit local circumstances of affordability and risk (Anderson et al. 2001).

4. Hamilton et al. (2005: 204) suggests that research should be directed towards the potential expansion of wastewater-irrigated products and their acceptability by consumers.

5. Need for risk assessment modeling related to soil and human health issues.

6. An analysis of recycled water schemes in relation to the broader regional infrastructure planning is needed (Kularatne et al. 2005: 26).

3. RESEARCH APPROACH: A Framework for Efficient Wastewater Recycling

A framework that can be used to describe the situation facing policymakers is presented in Figure 2. This schematic diagram can act as a guide to the approach pursued in this study. The central component of this approach is the physical pathway through which wastewater is generated, collected, treated and distributed, which is the common component for all the countries irrespective of their economic status. It is then argued that the emphasis on different phases of this pathway depends on the level of development in any region. As regions become more developed they concentrate on factors further down the pathway.

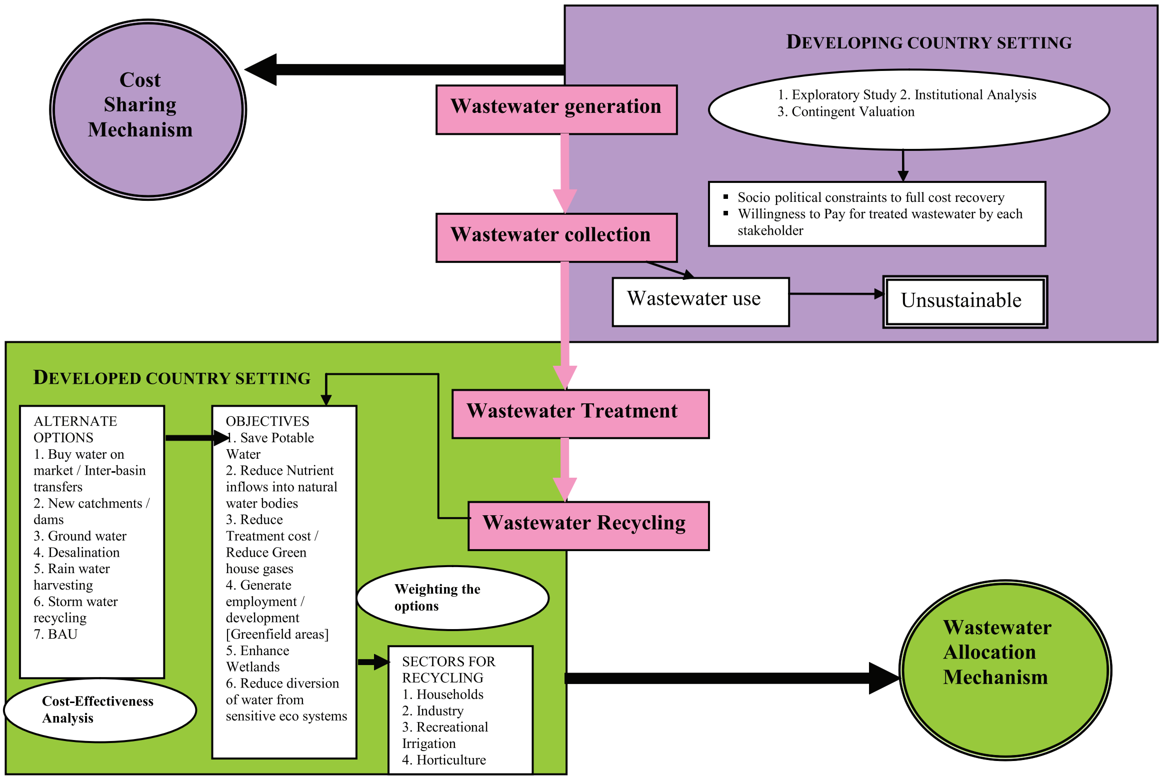

FIGURE 2. A framework for efficient wastewater recycling across nations

A typical pathway of wastewater consists of four phases:

A. **Wastewater generation:** With increasing urbanization and changing lifestyles, wastewater generated in the urban areas is large and continues to grow over time. As cities are the centers of political and economic power, their water needs usually receive a higher priority, but are subject to physical and economic scarcity constraints. Increases in urban water supply ensure increased wastewater generation. The depleted fraction of domestic and residential water use is typically only 15-25% and the remainder returns to wastewater (Scott et al. 2004).

B. **Wastewater collection:** Most cities in the developing world are only partially sewered, resulting in substantial volumes of wastewater (including toilet wastes) finding their way into surface water networks within cities. On an average only 28% of the population in the developing world in large cities is actually sewered, whereas more than 90% of the population is sewered in developed countries (WHO and UNICEF 2000).

C. **Wastewater treatment:** The sewage network is used to bring wastewater to the treatment plant. It can then be treated to primary, secondary or tertiary levels before it is discharged for further use or returned to a natural water body. Wastewater treatment is an expensive process, both in terms of the land required and the energy consumed. The percentage of total sewered wastewater that actually undergoes treatment to secondary level is 35% in

Asia. Almost no sewerage is treated in Africa and more than 65% is treated in developed countries (WHO and UNICEF 2000).

D. Wastewater discharge/use/recycling: In most developing countries, wastewater receives little or no treatment and is discharged into a river or lake from which farmers divert it into the fields to grow different crops. In many of the developed countries, wastewater is being recycled in a number of sectors other than agriculture for various reasons, but only after suitable treatment and guidelines are in place for recycling.

It is important to understand and establish that wastewater requirements of a region are dependent on the level of development of the societies within which they operate. The underlying assumption is that the degree of economic development of a region is a good indicator of the needs for different aspects of water recycling. The correctness of this assumption has been tested through a review of the literature. Literature has shown that in developing countries, a lack of treatment is the main problem of wastewater use practices and hence a strategy is needed to recover the costs of treatment from the different stakeholders. In developed countries, there is a need to increase the efficiency of recycling to reduce the cost of supply of recycled water so that it competes efficiently with alternate sources of water. The efficiency of recycling can be improved through a number of strategies at different levels: at the treatment level through new technologies; managing the demand and supply sides through information dissemination; appropriate pricing; through appropriate allocation among different sectors like domestic, industry, agriculture, recreation and environment. In the current paper, it is proposed to be done by increasing the allocative efficiency of treated wastewater.

Second, there is a necessity to develop the tools that allow for an evaluation of the feasibility of water recycling at different stages of economic development. There is no reason to believe that the tools that are required at one stage would be required at another. These tools should be based on the rational economic principles that tradeoff the benefits and costs over a long period of time.

Finally, there is a need to illustrate and apply these tools in different settings. For the current paper, the case studies of Melbourne, Australia (for the developed country setting) and Hyderabad, India (for the developing country setting) have been used.

3.1 Developing Country Setting

In developing countries a lack of sufficient funds, high treatment costs of the conventional treatment systems and rapid increases in wastewater volumes that exceed the current capacities of the treatment plants, results in a poor percentage of wastewater undergoing primary/secondary treatment. The farmers whose lands are along these water bodies often channel the partially treated or un-treated wastewater that is released into the rivers and lakes for irrigation. Though in the short run this water provides a reliable source of irrigation and income for these farmers, in the long run, it has adverse effects on the farmers' health, soil and also pollutes the groundwater thereby making the process unsustainable. It has been argued that state governments receive grants to cover the capital costs of treatment plants, but still do not have enough money to operate and maintain these treatment plants. Hence, the very need for their establishment fails. Therefore, an objective in this research, for the developing country setting, is to develop a strategy to recover treatment costs from the different stakeholders who directly benefit from the treatment and make the process self-sustaining and efficient in the long run. Through the Hyderabad case study, using institutional analysis and contingent valuation methods, this framework is tested for a developing country setting. See section, *Methodology*, for more details on the research methodology.

3.2 Developed Country Setting

In developed countries wastewater recycling is common in:

- Water scarce regions such as in Australia, Middle East and southwest of US,
- Regions with severe restrictions on disposal of treated wastewater effluents, such as Florida, coastal or inland areas of France and Italy, and
- Densely populated European countries such as England and Germany (Marsalek et al. 2002).

Even in high rainfall countries like Japan whose mean annual precipitation is 1,714 mm, urban wastewater use is common due to high population density in some regions, which suffer from water shortages (Ogoshi et al. 2001). The developed countries have generated techniques and guidelines for the safe use of wastewater, which can be adopted by developing countries. After reviewing many overseas recycling projects, Radcliffe (2004) concluded that worldwide, water use is becoming an increasingly common component of water resource planning as the costs of wastewater disposal rise and opportunities for conventional water supply development dwindle. However, the efficiency of recycling can be enhanced if the authorities and communities have a clear vision of the key objectives that need to be fulfilled in the long run through recycling which would then determine the particular sectors to which wastewater should be allocated. A combination of two techniques (which weight the objectives that a community wishes to achieve and cost-effectiveness analysis for wastewater recycling in different sectors) can be used to develop a decision support tool for efficient wastewater recycling in developed countries. The Melbourne case study will be used to test this framework for the developed country setting. See section, *Methodology*, for more details on the research methodology.

4. METHODOLOGY

Hyderabad Case Study

Hyderabad, the fifth largest city in India has been chosen as a case study to understand the wastewater situation of a developing country setting. Hyderabad is representative of a typical Asian city with high population density, a growing economy and grappling with the issues of water scarcity and pollution of rivers with urban sewage wastewater. In Hyderabad, India, less than 10% of wastewater is treated to secondary level due to high treatment costs and as a result pollutes the Musi River and creates environmental and health hazards for farmers who use this water in the downstream areas of the city. However, under a new project called “Save Musi Campaign”(SMC), four new treatment plants will be set up soon and it is mandated that all the wastewater that enters the Musi River will be treated to secondary level. The sewerage and sewage treatment components will be funded partially by a grant from National River Conservation Directorate [NRCD] for the sum of 70% of the cost and the remaining 30% will be funded by the Government of Andhra Pradesh.

Time and again it has been seen that state governments receive grants to cover the capital costs of treatment plants, but still do not have enough money for operation and maintenance of these treatment plants and hence the very goal of their establishment fails. Therefore, the contribution to the research goal through the Hyderabad case study will be through development of a strategy to recover treatment costs to ensure treatment of wastewater and contribute to sustainable recycling. The research hypothesis for the Hyderabad case study is: A mechanism of sharing the cost of the treatment of wastewater which can ensure treatment of wastewater to appropriate levels and hence make recycling relatively safer for developing countries. The research questions for the Hyderabad study are:

a) What are the institutional and sociopolitical constraints to fully recover the cost of wastewater treatment?

b) What could be the different settings of realistic cost sharing between polluters of water (households and industries), the government (local, state and national level), funding agencies (as loans or grants from donors and other financial institutions) and users of recycled water (industries, farmers, urban authorities controlling parks)?

The expected output from the Hyderabad case study would be to develop a strategy of realistic cost-sharing between different stakeholders to recover treatment costs to ensure treatment of wastewater to appropriate levels and make the process of recycling self-sustaining and less harmful to the environment and human health.

For Hyderabad, the research will be conducted in three stages: exploratory study, institutional analysis and contingent valuation.

4.1 Exploratory Study

The exploratory study has been carried out in Stage I to understand the wastewater situation, cost recovery for wastewater treatment facilities and future plans for maintenance, analyze the extent of subsidization for water and sewerage services, the current deficit in cost recovery and additional funds required to treat 100% of wastewater at least to secondary level.

Current literature review and secondary data reveals that Hyderabad Metro Water Supply and Sewerage Board [HMWSSB] recovers its water supply charges and any deficits in supply costs by cross subsidization from high water consumption industries or households. The water supply charges cover the operation and maintenance costs, but do not cover the capital costs of the water supply infrastructure. The government and other donors cover the capital costs of water supply.

Only 35% of the water supply charges are charged to consumers as sewerage cess. As a result, the HMWSSB has no money to cover their treatment costs and hence about 90% of the wastewater produced is un-treated and released into the Musi River which is used by the farmers downstream for irrigating the crops resulting in groundwater pollution in those vicinities, soil contamination and crop yield reductions. To control these ill effects, there is an urgent need to treat the wastewater before it is released into the river and this is possible only when the pricing of water includes the economic costs. Under the Musi River Conservation Project, there is a plan to construct four new wastewater treatment plants. The pricing of water and wastewater will be highly relevant for the HMWSSB, after the construction of these new treatment plants. According to the current plans, the HMWSSB intends to increase the sewerage cess from 35 to 50% to cover part of the treatment costs.

4.2 Institutional Analysis

In Stage II an institutional analysis was conducted to determine the institutional and sociopolitical constraints to wastewater treatment and the contingent valuation technique is used to determine the willingness of people to pay for sewerage charges. Under the institutional assessment (Bandaragoda 2000: 21), the following research questions will be relevant in a search for appropriate cost sharing strategies:

1. Who are the present actors in water and wastewater supply and management in Hyderabad?

2. What are the present patterns of wastewater use?

3. What is the legal framework within which wastewater as a resource operates and controlled?

4. What is the current pricing and cost recovery policy for wastewater treatment?

5. What is the nature of conflicts and how are they resolved?

6. What will be the future trends and settings with reference to use, access and cost division of treatment of wastewater?

The main components of the water institutions that need to be looked at will include wastewater related law, water policy and water administration. Box 1 shows the components of institutional analysis.

BOX 1.

Components of the water institutions to be studied for institutional analysis.

a) Wastewater Law

- Legal coverage of wastewater and related resources
- Wastewater rights
- Provisions for accountability
- Scope for public/private sector participation
- Regulatory mechanisms
- Integration of overall legal framework with water law

b) Wastewater related Policy

- Policy on river conservation
- New wastewater related projects
- Pricing and cost recovery
- Treated wastewater allocation and transfers
- Linkages with other economic policies

c) Wastewater related Administration

- Formal organizations
- Organizational procedures
- Pricing, finance and accountability mechanisms
- Information, research and extension systems

Source: Adapted from Bandaragoda 2000: 34 for this study

4.3 Contingent Valuation

In stage III different scenarios of realistic cost sharing between polluters of water (households and industries), the government (local, state and national level), funding agencies (as loans or grants from donors and other institutions) and users of recycled water (industries and commercial farmers), will be developed based on the results of stage II. The contingent Valuation technique will be used to assess the willingness to pay for the recycled water by each group of stakeholders.

The contingent valuation technique is called so, because it is contingent on simulating in a questionnaire a market in which behavior can be modeled. It has a great appeal in estimating the value of a benefit with the simple question – what is the maximum you would be willing to pay for it? The response should be an estimate of the total benefit that the person expects from the particular item and subtraction of the appropriate costs should provide an estimate of the consumer's surplus (Sinden and Thampapillai 1995). However, one can face a number of problems while using the method.

4.3.1 Problems that can be encountered

The major difficulties with the method are the potential biases in the questionnaire and survey. The range of biases in the survey reviewed by Mitchell and Carson (1989) are as follows:

a) Payment-vehicle bias: Willingness-to-pay is framed in some kind of payment and if the subject is asked to pay, say, higher taxes or higher travel costs and if the subject dislikes that particular kind of payment, he/she might understate the true willingness to pay. Pre-surveys can be used to check such a bias.

b) Information bias: Willingness-to-pay responses may vary with the quantity and quality of information, which is provided. This bias can be avoided by providing the maximum amount of information in the questionnaire within the space constraint and identical information provided to each subject.

c) Starting point bias: The Yes/No direct question requires values ($X) to be nominated as 'starting points'. Sometimes, when the subject is bored with the survey, he may agree to the bid even though his true willingness-to-pay differs substantially. Pre-surveys to discover likely starting points may be useful to avoid such a bias.

4.3.2 Checks to ensure validity of responses

Questionnaire surveys may be well established, but they elicit responses to hypothetical questions in hypothetical contexts and hence precautions should be taken to ensure validity of the data collected. Valid values may be obtained by using the following checks (Sinden and Thampapillai 1995):

a) Contingent-validity test: Design of the survey and questionnaires should ensure that the kind of persons who play strategic games are identified and excluded, incentives to play games are removed, and incentives for valid responses should be provided.

b) Comparison test: Hypothetical bids are checked against bids elicited by some other method, against payments of a related nature or against preferences and attitudes.

c) Internal-consistency test: Differences in values should be consistent with difference in characteristics of the respondents. For example, willingness-to-pay should often increase with income. A statistical test, to show that values do vary with the income in the expected manner, supports the validity of the values themselves.

Melbourne Case Study

The drought conditions of the past seven years in Australia and increasing environmental awareness has led to an active promotion of wastewater recycling. The absolute and the relative cost of recycling is one of the key factors that have a significant influence on the future of wastewater recycling in Australia.

Therefore, the contribution to the research goal through the Melbourne case study will be through the development of a tool kit/decision support tool that can be employed to allocate wastewater among different sectors to achieve the desired objectives in a cost-efficient way. The research hypothesis for the Melbourne case study is: Treated wastewater recycling is a viable economic option only to the extent of its defined objective within the boundaries of a given budget. The research for the Melbourne case study is an attempt to address the following research questions:

a) What are the objectives based on which the cost-effectiveness of wastewater recycling should be judged and budget accordingly allocated?

b) What are the different sectors within a defined region in which wastewater recycling is cost-efficient?

The expected output from the Melbourne case study (i.e., developed country setting) would be to develop a tool kit/decision support tool that can be employed to allocate wastewater among different sectors to achieve the desired objectives in a cost-efficient way.

Wastewater has a number of alternative uses and each alternative is associated with a set a costs from the point of treatment to the point of use. Accordingly, wastewater recycling can satisfy more than one objective like: reduce the discharge of nutrients to natural water bodies, save/substitute potable water, bring more land under cultivation, save water for environmental purposes and so on. The methodology chosen to evaluate the best alternative or alternatives for this research is the Cost-Effectiveness Analysis. However, the cost-effectiveness of a particular objective depends on the objective that one wants to achieve. Therefore, a ranking exercise will be conducted for the different objectives among the stakeholders and each objective would be weighted accordingly. A further step in the research depending upon the objective, i.e., if the objective is to complement the urban water sources, would be to compare the cost-effectiveness of wastewater recycling versus other options like buying water on the market from the agricultural sector and desalination. It is hoped that the approach outlined above may prove to be the basis of a tool kit/decision support tool that can be employed in other circumstances and regions to allocate wastewater among different sectors.

4.4 Cost-effectiveness Analysis

Cost-Effectiveness Analysis [CEA] is one of the techniques for economic evaluation in which all costs are related to a single common effect. It is designed to compare the costs-effectiveness of an intervention and determine if the intervention is worth doing (Phillips and Thompson 2001). According to Eddy (2000), it is a technique for selecting among competing wants wherever resources are limited. Weinstein and Stason introduced it to clinicians in 1977 and was first applied to health care to make decisions on appropriate strategies to increase health benefits or cost savings.

In cost-effectiveness analysis, a new strategy is compared with the current practice (which may include doing nothing). Only if the new strategy is associated with enhanced effects and higher costs, cost-effectiveness analysis is required. It is compared against current practice (the "low-cost alternative") in the calculation of the incremental CE ratio:

$$\text{CE Ratio} = \frac{\text{Cost}_{\text{new strategy}} - \text{Cost}_{\text{current practice}}}{\text{Effect}_{\text{new strategy}} - \text{Effect}_{\text{current practice}}}$$

The result might be considered as the "price" of the additional outcome purchased by switching from the current practice to the new strategy.

The choice of technique depends on the nature of the benefits specified. According to Phillips and Thompson (2001) in CEA, the benefits are expressed in non-monetary terms and in the cost-benefit analysis they are expressed in monetary terms. As with all economic evaluation techniques, the aim of CEA is to maximize the level of benefits relative to the resources available.

In Cost-Effectiveness Analysis, it is conventional to distinguish between the direct costs and the indirect costs associated with the intervention, together with intangible positive and negative externalities, which although they may be difficult to quantify, are often consequences of the intervention and should be included in the cost profile. The costs to be considered for Cost-Effectiveness Analysis of recycling projects are:

- Direct costs: includes capital costs of treatment and distribution of recycled water
- Indirect costs: For example, groundwater pollution of areas irrigated with recycled water
- Intangibles: includes yuck factor, non-acceptability of the wastewater irrigated products

It is important to specify which costs should be included in a Cost-Effectiveness Analysis and which should not, to ensure that the findings are not subject to misinterpretation. A distinction must be made between those interventions that are completely **independent** – i.e., where the costs and effects of one intervention are not affected by the introduction or otherwise of other interventions – and those that are **mutually exclusive** – i.e., where implementing one intervention means that another cannot be implemented, or where the implementation of one intervention results in changes to the costs and effects of another. For the current study, wastewater recycling can be considered to be an independent programme. Using Cost-Effectiveness Analysis with independent programmes requires that cost-effectiveness ratios (CERs) are calculated for each programme and placed in rank order.

$$\text{CER} = \frac{\text{Costs of intervention}}{\text{Effects produced}}$$

Interventions with the least CER should be given priority but in order to decide which programme to implement, the extent of resources available must be considered. In mutually exclusive interventions, incremental cost-effectiveness ratios (ICERs) are used:

$$\text{ICER} = \frac{\text{Difference in costs between programmes P1 and P2}}{\text{Difference in effects between programmes P1 and P2}}$$

The alternative interventions are ranked according to their effectiveness – on the basis of securing maximum effect rather than considering cost – and ICERs are calculated.

The results of Cost-Effectiveness Analysis should be subjected to a sensitivity analysis. Since the Cost-Effectiveness Ratios are point estimates, which by definition have uncertainty around them, means that CERs require some indication of the confidence that can be placed in them. In a dynamic market situation, both the costs and the effects are liable to changes. Sensitivity analysis tests all assumptions used in the model and enable the impact of the best-case and worse-case settings on the baseline findings to be investigated.

4.4.1 Procedure for conducting the Cost-Effectiveness Analysis

The four sectors where wastewater can be recycled and for which the CEA will be conducted for the Melbourne case study are household/residential, industry, recreational irrigation and agriculture. The cost-effectiveness of using recycled water for each of the sectors is obtained by summing the costs of using recycled water for each of the options (which includes the cost of treatment to comply with the EPA standards for each of the specific uses and to take it to the point for use) and dividing this cost by the intended impact it creates depending upon the objective one (Melbourne Water/Victoria State Government) chooses to attain.

a) Costs to be included for Cost-Effectiveness Analysis

In a stakeholder consultation conducted for the research to identify impediments to recycling, by ACIL Tasman Pty Ltd. (2005), an overwhelming majority (77%) of stakeholders identified the cost of infrastructure as an important impediment to the supply side of the recycled water market. Water companies can invest in recycling infrastructure only if they are financially viable and worth the risk. Therefore, the cost of supplying recycled water becomes a crucial determinant of overall project viability. It is important to recognize that the direct costs of providing recycled water will depend on the specific nature of the project and the use to which the recycled water will be put.

ACIL Tasman Pty Ltd. (2005) broadly categorized the infrastructure related costs associated with recycling as:

- Capital costs for new or upgrading of treatment plants, and subsequent operating costs;
- Installation and operation of reticulation and trunk delivery systems;
- Storage capacity where needed to match seasonal variations in production and demand; and
- Costs incurred by users in accessing recycled water (e.g., conversion of equipment, plumbing, additional on-site storage or treatment, etc.).

Other costs of supply such as:

- Project planning and regulatory approvals,
- Marketing, public education and consultation programs;
- Capital and operating costs of any additional treatment and waste-stream treatment following recycled water use;
- Ongoing monitoring and compliance with regulatory requirements and other risk management measures;
- Contingent liabilities for possible legal claims arising from inappropriate use of the recycled water; and
- Metering, billing, and other customer-related costs.

The capital and operating costs of treating wastewater to a standard suitable for its intended use will depend upon factors such as the quality of the effluent, the quality of the recycled water required, the technology adopted or required for the appropriate level of treatment, and the extent of economies of scale. The general position is that the higher the level of treatment, the higher the cost. The relative cost-effectiveness of recycled water schemes in terms of cost per megaliter varies significantly from project to project, with a high volume of industrial or agricultural schemes benefiting from economies of scale. A common issue raised by suppliers consulted in this research was the challenge and costs associated with overcoming the spatial separation of supply.

b) Objectives of wastewater recycling

The objectives of a state government for recycling might be varied. Depending on the objective, the results of the Cost-Effectiveness Analysis will vary. The different possible objectives are shown in Table 1.

Depending on the objective (see Table 1) that an institution/community wants to achieve, the sector to which the recycled water is allocated would vary and so would the costs and its effectiveness. It is also possible that the state government/community has multiple objectives that it wants to achieve through recycling. In such instances, there is a need to prioritise/rank/weight the different objectives according to their perceived importance.

TABLE 1. Possible objectives of recycling and the expected effect.

Objective	Criteria for Effectiveness (AUD/Effect)
To reduce the nitrogen load released into the bay	AUD/tons of Nitrogen discharge reduced into bay/river
To save potable water or create alternative or new sources of water to complement the existing sources	AUD/gallons (GL) of potable water saved
To reduce the costs of treatment by treating the water to a lower level	AUD/kiloliters of wastewater treated
To promote regional development in new areas through employment generation and promotion of primary industries	AUD/number of people employed

4.5 Weighting Objectives of Recycling

The options for wastewater recycling are varied and contentious because of its nature of origin and issues and perceptions related to health and safety. The local communities have rejected a number of wastewater recycling projects by the government and water boards around the world and in Australia. A number of social reasons have been found to be associated with the rejection:

1. Lack of coordination between the authorities involved in planning health, water supply and environment, and inadequate community consultation on the issue (PMSEIC 2003).

2. Lack of trust in technology: In the study conducted by Sydney Water (1999), the lack of trust in technology was the second most frequently stated reason stated by participants who were in opposition to using reclaimed water for agricultural irrigation.

3. Social pressure and fear of social backlash: A heightened need for new water sources does not automatically warrant the acceptability of wastewater recycling. The drought affected Werribee farmers were offered a deal to access water from the Thompson Dam by the Victorian Government (ABC online 2004) in 2004, in return for which, the farmers were required to sign up to a program to take reclaimed water the following year. Only half of the Werribee farmers have so far accepted the deal. Others are reluctant due to fears of possible community backlash.

4. Fear of losing markets: According to Boland (2005), the greatest concern for growers is maintenance of markets – continued access and assured price. A recent survey by the Department of Primary Industries, where the consumers were asked if they would be willing to buy vegetables grown in Werribee with recycled water showed the following results (Boland 2005):

Yes	35 %	Support the use of recycled water; trust the authorities to do the right thing
Not sure	55 %	If the water is treated properly; if safety is guaranteed
No	10 %	Don’t like the idea of using recycled water

Literature review and previous studies have consistently shown that the closer one moved on the contact continuum, the less acceptable the recycling option became. The acceptability of using recycled water is higher for non-edible crops than for edible crops. For edible crops, preference is towards crops that must be peeled or washed prior to human consumption like oranges, sweetcorn (D'Angelo Report 1998).

However, when Bruvold (1988) conducted a study using salient options, which specifically described how and when the recycled water was to be used in a community, he found that the degree of contact was not related to how acceptable people perceived a certain use option was. In his study, participants favored specific use options, which conserved water, enhanced health and reduced treatment and distribution costs. He collated all the factors that influenced overall public perceptions of use as (1) degree of human contact, and (2) the five factors (i.e., health, environment, treatment, distribution and conservation). He asserted that the first component only had a greater effect when people were asked about general use options, whereas when the specific use scheme was used, the second component had greater impact on people's perceptions.

Therefore, it is essential to weigh the different objectives of the government for recycling options in coordination with peoples/users acceptability and preference and accordingly select the recycling projects which are most likely to be accepted by the community and therefore make the project implementation successful. The different weighting methods include: equal weighting of all attributes, rank order weighting and ratio weighting. In a simulation study done by Jia et al. (1993), it was found that ratio weights and rank order weights were substantially superior to the equal weights method.

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